FUNDAMENTALS OF ENERGY TRANSFER

I agree with Chris Parton's attack on the definition of electric current, *Wireless World,* December, 1984, page 65.

Parton discusses "Forces on conductors guiding a TEM wave." I have a chapter with that title in vol. 2 of my book, Electromagnetic Theory. I feel that these strange forces may guide us to a unified field theory.

Force on conductors guiding a TEM wave

After a TEM wave step has passed by, guided by two parallel conductors, there remain two steady state "fields":

(1) Electric current flows down the wires, and a B field exists in the dielectric right next to the surface of the conductor.

(2) Electric charge remains on the surface of the conductors, and an E field exists in the dielectric right next to the conductor.

The magnetic field exerts a force into the conductor; that is, a force which tends to drive the conductors apart. The electric field exerts a force out of the conductor; that is, a force which tends to pull the two conductors together.

The forces are $F_1 = iB$, $F_2 = qE$. Now the electric current in the surface of the conductor i and the electric charge in the surface of the conductor q are related by the equation $i = q \odot$. That is, the current is equal to the speed with which the charge density travels along the surface of the conductor. Dividing, we find that numerically:

$$\frac{F_1}{F_2} = \frac{iB}{qE} = \frac{\odot B}{E} = \frac{1(\mu H)}{\sqrt{\mu \cdot E}} = \sqrt{\frac{\mu}{E}} \frac{H}{E}$$

But we know that in a TEM wave,

at every point $E/H = \sqrt{\mu / E} \; \mu$
Therefore $F_1 = F_2$ numerically.

We conclude that when a TEM wave (which we call a Heaviside signal) glides along between two conductors at the speed of light, there is no force on the conductors guiding the signal. This very interesting feature of a Heaviside signal was first pointed out by David Walton, and is here proved.

C.A.H.
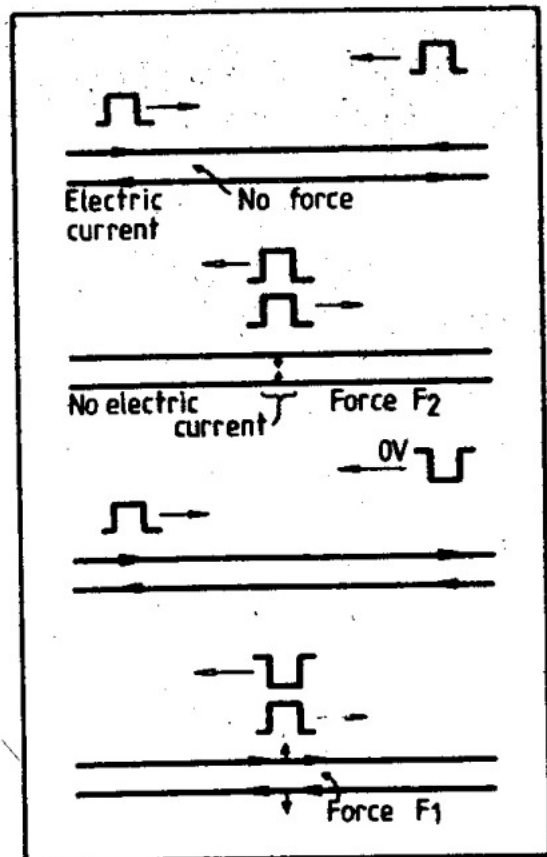
(For the equations giving F_1 and F_2, see for instance P. Hammond, "Electromagnetism for Engineers", Pergamon, 1978, pages 107 and 55.)

It is generally thought that if an electromagnetic wave travels down a coax cable from left to right and passes through another such wave travelling from right to left, then superposition applies. However, this is not true in the very important matter of the forces on the conductors. Where each wave on its own exerts no force, (the electric force and magnetic force cancelling,) when two waves are passing through each other one of the "fields" E or B — cancels, and we are left with a net force resulting from the non-cancelling "field". So superposition does not strictly apply, because when we superpose two TEM waves, something new suddenly appears, a physical force. If the two pulses passing in opposite directions are of the same polarity, another strange thing happens for the short time during which they overlap. That is, there is no electric current in the surface of the conductors. So if the conductors are imperfect, there is no resistive loss during that short period of time. (Similarly, if the pulses have opposite polarity, then if the dielectric is imperfect, there will be no losses due to leakage during the short period of pulse overlap.)

Ivor Catt
St. Albans
Hertfordshire

I am not very surprised to notice that many readers of *Wireless World* (e.g. N.C. Hawkes, December, 1984) have been finding difficulty in appreciating the contradiction implicit in classical electromagnetic theory pointed out by Ivor Catt (September, 1984).

A slow drift of electrons along a wire may well account for a "steady state" movement of charge, and until recently it seems that this was all that was required.

However, with the growing importance of high-speed logical signals, new problems have been brought into the limelight which are inexplicable purely in terms of classical "electron drift".

I will attempt to explain the "Catt anomaly" from a slightly different angle in the hope that this may serve to shed more light on the contradiction.
(i) Experiment shows that a voltage "step" travels at the speed of light (of the dielectric between the wires).
(ii) Classical theory tells us that electrons cannot travel at the speed of light because they have a finite rest mass. (At normal temperatures the average speed of the free electrons is of the order of 1/1000 of the speed of light). In fact the "drift velocity" of the free electrons turns out be much smaller, (of the order of 1cm/second).

C.A.M.

(iii) Electrons in a given section of wire will not start to "drift" until they have received the message to do so.

(iv) The signal which tells the electrons to move is the electric field caused by the charge on the electrons which have drifted in another section of the wire. Thus the signal resulting from the change in electric field (the voltage step) travels at the drift velocity of the electrons.

The contradiction and resulting inadequacy of the theory is clear to see.

This, the "Catt anomaly", seems to have fallen on many deaf ears. I am interested to see how the scientific community continues to react to this vitally important breakthrough, which could lead to a revolution in electromagnetic theory.

F.U. Weaver-Mowes
Sutton
Surrey

With reference to the correspondence concerning the physical mechanism of energy transfer along transmission lines. I believe that Catt is correct in insisting that something much faster than electrons is involved. It seems reasonable to assume that as the electrons in the wires would be continuously entering and leaving the conduction band, there would be a corresponding traffic of the associated quanta, at the velocity of light, and that it is the existence of these quanta that constitutes the basis of the energy transfer mechanism. By considering all the quanta that at any given time travel in one direction along a wire as one energy current, and the contrary travelling quanta as an opposite current, Catt could justifiably speak of two superimposed slabs of energy and explain the experimental facts in connection with 1 metre long transmission line reported on page 80 of the December, 1980 issue.

I expect that the above suggestion, if correct, will lead to revised understanding of conduction phenomena generally, including such topics as superconductivity and the action of thermocouples.

G. Berzins
Camberley
Surrey

ELECTROMAGNE-TIC ENERGY TRANSFER

I would like to reply to letters in the January issue following my article in September and October of 1984.

I regret that I cannot comment on P.J. Ratcliffe, since I see no reason for mixing e-m and entropy. Have they been mixed up together before, I wonder?

Ouida Dogg (sic) compares Galileo's travails with mine. Certainly the scandalous, unprofessional behaviour of the Establishment (in my case officials of the I.E.E., Inst. Phys. etc.) closely parallels that of the Church in Galileo's case, except that the Church and its supporters at least bothered to supply some philosophical justification for what they did to Galileo. Disclosure of my research has been delayed for more than ten expensive years. There is no point in giving names, because every single member of the scientific establishment behaved irresponsibly in my case. As Oliver Heaviside wrote;

"If you have got anything new, in substance or in method, and want to propagate it rapidly, you need not expect anything but hindrance from the old practitioner — even though he sat at the feet of Faraday.

Beetles could do that. . . But only give him plenty of rope, and when [as now in my case] the new views have become fasionably current, he may find it worth his while to adopt them, though, perhaps, in somewhat sneaking manner, not unmixed with bluster, and make believe he knew all about it when he was a little boy!" — See I. Catt et al., Digital Electronic Design vol 2, p323, pub. C.A.M. Publishing.
Ivor Catt
St. Albans
Herts.

The NPL definition of the ampere is bad science purely because of the difficulty in getting infinitely long conductors. If we are to imagine them as the definition requires, we must make sure that they are a fair extrapolation of the finite shorted line. Chris Parton (December, 1984) gets into a tangle as he unwinds his reels of wire to infinity because he assumes they are initially quiescent. Why not extend the forward and backward wave system of the finite case to infinity along with the conductors? If you must speculate how this could be set up in a finite time from a quiescent state, why not allow a distributed e.m.f. instead of applying it at one point?

On the subject of transmission lines, Ivor Catt,

who provoked this discussion, should get his car seen to if, as he says, it suffers from an energy dance at the speed of light. Wot no dielectric insulation? I hate to think what reflections will build up when the conductors touch.

Finally I was intrigued to learn from Mr O'Reilly that open lines are 'always terminated by free space with an approximate impedance of 377 ohms'. This should be of considerable interest to transmitter designers, especially at e.l.f., where they have great difficulty in getting anything radiated at all. But now all they have to do is install a 377 ohm feeder to the outside where it is cut off cleanly. The r.f. will run up the line and obligingly launch itself into free space unhampered by any aerial. Since this effect is independent of frequency, or even geometry, it must be explanation of another phenomenon which has always puzzled me: the fact that my batteries always go flat during storage. Obviously they are being shunted by free space. It would also explain the well-known standby consumption of mains sockets, amounting to 153 watts, if they are not properly switched off at the wall, a fact well appreciated by builders in these energy conscious days, when it comes to specifying the number of sockets in a room. This effect

was, in fact, first brought to public attention by James Thurber, whose aunt lived in dread of electricity leaking out and getting around the house.
D.H. Potter
Axminster
Devon

MAY 1985

THE CATT ANOMALY

I feel I must assert that I really exist. I was in no position to protest when my parents devised my ridiculous name.

Now, following Ouida Dogg, who turned up again in January, we find Weaver-Mowes joining the act in February. This latest joker purports to be supporting me strongly.

The storm-troopers for the Establishment are happy to be identified, but dissidents tend to feel they need some camouflage. It's short-sighted, because, looking through back numbers, I find that the mean-free-path of the Establishment running-dogs is frighteningly short.

Referring to the W-M letter in February, p.77, I think the most convincing approach to

the "Catt anomaly" (*WW* Sept. 84, p.48) is to concentrate on the electric *charge* on the bottom wire. W-M discusses an associated anomaly; the problem of how the electric *current* can come up to scratch. I want people to be forced to face up to the more glaring problem of *charge.* I suggest that the problem of *current* be termed the "Mouse anomaly".

When referring to the problem more generally, one would call it the "Catt and Mouse anomaly". In Feb 85 you published a letter from G. Berzins which demonstrates a failure of comprehension which may be widespread, and so merits discussion. He thinks it is possible for the energy in a TEM wave guided by two conductors, to be transferred by some mechanism within the   This notion leads to a reductio ad absurdum.

Consider a parallel plate transmission line of characteristic impedance 10 ohms. A TEM step of amplitude 100 volts is travelling down between the conductors. Power is being transferred at the rate of 1,000 watts. According to Theories N or H, electric current and electric charge exist in/on the two conductors.

Now consider a similar parallel plate transmission line lying immediately beneath the lower conductor. Again, it has a characteristic impedance of 10 ohms and a TEM step of 100 volts is travelling down between the conductors. Electric current and charge exist in/on the two conductors. The current and charge in the new upper conductor is exactly equal and opposite to that in the lower conductor of the original transmission line, immediately above it. Now all theories will claim that the activity in each of the four conductors is similar. If this activity is the mechanism for energy transfer, then total energy transfer, 2,000 watts, is made up from four contributions.

Now supposing the middle two conductors are very close together, and they become closer. Still we have four contributions to the energy transfer. Now reduce the middle two conductors to wafer thin, and then remove them. (During this process, the activity in top and bottom conductors will not change). Hey, presto! Current and

charge in the two middle conductors cancel to zero, and the same activity in the surviving top and bottom conductors, previously responsible for the transfer of only 1,000 watts, now transfers 2,000 watts!

Ivor Catt
St Albans
Hertfordshire

C.A.M.

FUNDAMENTALS OF ENERGY TRANSFER

Mr Catt evidently assumes that the often-repeated statement that the field round a transmission line if TEM has been proved. But has it?. If there is a proof that the electric field is everywhere strictly transverse then, please believe me. I would be really glad to see it.

The proof would have to deal with the following point. As a step wave passes down the line it sets in motion the electrons in the conductors. That is, the electrons are given (kinetic) energy by the field. Hence, somewhere, energy passes through the surface of each conductor, that is, somewhere there is a component of the Poynting vectro into the conductor. So somewhere, there is a component of electric field along the conductor.

P.L. Taylor
Marple
Cheshire

I believe Mr Catt (Letters, February 1985) has made an error.

He seems to be saying that the principle of superposition should apply to the situation he describes — the case of the forces between conductors carrying overlapping pulses. It is, of course, wrong to try to apply superposition here, since the equations he has written down for his forces F_1 and F_2 are not linear (as superposition demands), but quadratic.

The equations

$$F_1 = iB \text{ and } F_2 = qE$$

appear at first sight to be linear, but since B is itself proportional to i, and E to q

$$F_1 = k_1 i^2 \text{ and } F_2 = k_2 q^2$$

Thus the forces are quadratic functions of the current and charge on the conductors and linear superposition is invalid. We should therefore not be surprised by the appearance of these 'strange' forces.

This is perhaps more clearly illustrated by the corresponding problem in electrostatics. The forces on a positively and

C.A.M.

Fig.1   Fig.2   Fig.3
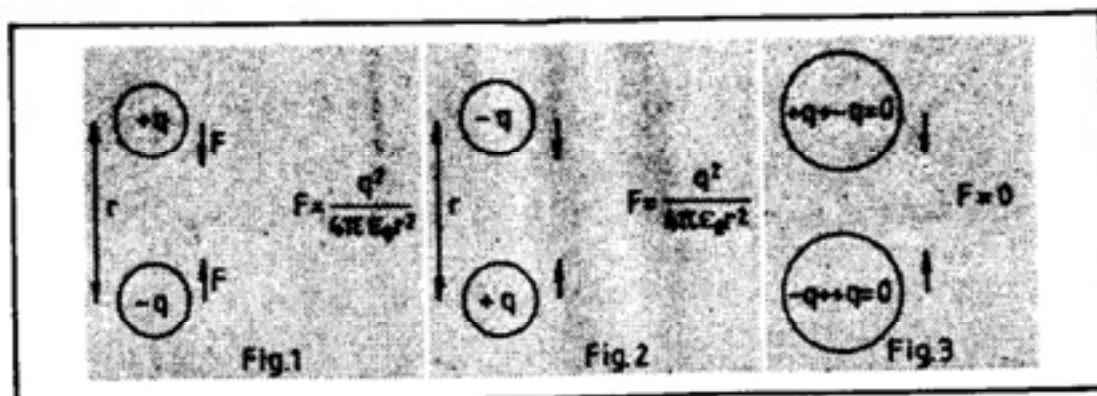
negatively charged sphere are shown in Fig 1.

The forces on the spheres in Fig. 2 are the same in magnitude and sign. However, in the situation of Fig. 3 where we have superposed the charges on the spheres from Figs 1 and 2, we find that the forces disappear.

If Mr Catt is searching for unification of electric and magnetic forces, he may be interested to consider the following.

In the double beam c.r.o. mentioned in Chris Parton's letter (December, 1984), the force per unit length on each beam of electrons can be written as the sum of the electrostatic repulsion and magnetic attraction

$$F = \frac{\mu_o I^2}{2\pi a} - \frac{q^2}{2\pi \epsilon_o a}$$

where a is the separation of the two beams.

But, if you transform to the rest frame of the electrons, travelling at speed v, the magnetic field disappears since the charges are now at rest.

Now, if q is the charge per unit length in the beams in the laboratory frame, then the length part of q must be Lorentz transformed to q′ giving

$$q' = q/\gamma$$

where $\gamma = (1 - v^2/c^2)^{-\frac{1}{2}}$.

Thus the electrostatic repulsive force can be rewritten

$$F = \frac{q'^2}{2\pi \epsilon_o a} = \frac{q^2 v^2}{2\pi \epsilon_o a c^2} - \frac{q^2}{2\pi \epsilon_o a}$$

Finally, substituting

$$C^2 = \frac{1}{\mu_o \epsilon_o}$$

where the current in the beams is I—q.v, we have

$$F = \frac{I^2 \mu_o}{2\pi a} - \frac{q^2}{2\pi \epsilon_o a}$$

which is exactly the same force as we derived using magnetic theory.

C.A.M.

This is a general result embodied in the relativistic invariance of Maxwell's equations and may be considered to be the unification of electromagnetic and electrostatic field theory.

N.C. Hawkes
Abingdon
Oxfordshire

JULY 1985

FUNDAMENTALS OF ENERGY TRANSFER

P.L. Taylor (Letters, June 1985) is unfair to me, probably because he has not read much of my writings. The whole thrust of "The Catt Anomaly" (*WW* Sept 1984, p.48) is that the conventional theory (which I call Theory N) contains logical inconsistency when it tries to explain the TEM wave, because electrons are involved. I base the case for my own theory, Theory C (*WW* Dec 1982 and Oct 1984) on the point Taylor is making. Does he really expect me to defend the conventional theory, which I habitually attack, for his benefit?

N.C. Hawkes (Letters, June 1985) misunderstood my February letter. He discusses the force between charged conductors and the force between conductors carrying current, whereas I am discussing the force between two conductors between which a TEM wave is travelling. I only mentioned charged conductors and current-carrying conductors in passing, in order to prove that the force between conductors between which a TEM wave is travelling is zero. Having established that the force is zero, I then proceeded to superpose two TEM waves. Hawkes has put the cart before the horse and turned them round and upside down.

I congratulate C.B.V. Francksen (*WW* May 85) on the first two and last three paragraphs of his letter.

My own position is that "modern physics", as the Establishment developments in our field during this century are termed, is a collage of layer upon layer of muddle, misconception and confusion. We do not just have a problem of one or two errors in the structure. The whole is riddled with error, and a false philosophy of science has developed to buttress it. When it collapses, the effect will be devastating. I do not believe we shall save much fundamental theory from the mess of the twentieth century.

What we *can* do is try to get more study going on the politics, the sociology and the self-seeking contained within the science of this century, so as to learn the lessons we shall need in order to stop a similar

C.A.M.

mess from engulfing the science of the twenty-first century. We musy learn why apparently clever men succumb to such a welter of arrant nonsense; what part of their action stems from self-interest; what part from lack of mental agility and what part from the very narrow education that scientists are subjected to.

Ivor Catt
St Albans
Hertforshire

It is quite easy by pejorative writing to attack, as D.H. Potter does in *WW* April, 1985, Ivor Catt and myself. If will need somewhat more skill and persistence to attack the ideas put forward. Mr Potter says in his letter that I assume the lines initially quiescent, but I am not aware of having said that, any more than I am of unwinding reels to infinity. I simply assumed, as the SI definition of the ampere requires, that a current of 1 A is established in the conductors. How that current is set up is of no concern, since the measurement is done *after* the current is established. There was a slight error in the diagrams reproduced in *WW* that may have caused some confusion although the text was reasonably complete without the diagrams. I will give a numerical example that will, I hope, illustrate my point.

It has been long established, and I take no issue with it, that if we have a transmission line passing through a partition, no measurement that is done at the sending end can determine whether the line beyond the
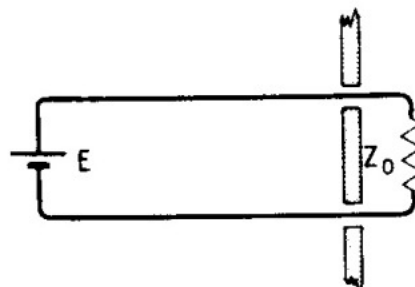
parition extends to infinity or is terminated in its characteristic impedance. A practical man of course would have doubts and put his head round the partition to see. The diagram shows such a line terminated in Z_0. Force may be measured on a metre length on the left hand side of the partition and the results will apply to the infinite line.

Consider a line that is not too different from that of the SI definition. The conductors could be 4mm diameter spaced 1m. It is easy to calculate that $Z_0 = 745\Omega$ and the capacitance per metre is 4.747 pF. Thus the value of E necessary to establish a current of 1 A is 745 V and that p.d. produces a charge per metre of 3.36 nC. The force between two such charges at a distance of 1 m is 2×10^{-7} N, which is the same as the magnetic force between the conductors when carrying 1 A, and in the opposite sense so

that the net force is zero. Ivor Catt reaches the same conclusion, but by a different method.

I had not intended to enter into a prolonged discussion on this matter for I have taken it up before in *Physics Education*, a journal of the Institute of Physics. The issues concerned are Nov 1981, Mar 1982, Nov 1982, May 1983 and July 1983. Indeed if Mr Potter cares to consult the July 1983 issue of *Physics Education* he will find Professor R.G. Chambers stating my case rather more strongly than I did myself.

The question not unnaturally rises, if the ampere is always realised with an Ayrton-Jones balance, then why not define it in terms of that apparatus? It is as easy to specify circular conductors as straight ones, and clearly the manufacturing tolerances are as good in one case as the other.

One point on which I do agree with Mr Potter is the slovenly use of the term *impedance of free space*. The word *impedance* is a bad choice and *impedivity* or *specific impedance* would be better for it is an impedance measured in a specified way. What is referred to is a superficial resistivity of 377Ω/square. Space card is paper loaded with conducting particles such that if we cut a square from it with arbitrary length of side, the resistance between two opposite edges is 377Ω. Any air-spaced transmission line passing through snugly fitting holes in the space card will have all its energy absorbed by the card and there will be no reflections.

I have said snugly fitting holes since I feel that the card should make good electrical contact with the conductors. However that may not be necessary. Heaviside, Poynting, and Ivor Catt all believe that transmission line energy is carried by the dielectric and only guided by the conductors. Space card may offer a way of testing that hypothesis. If the conductors are varnished where they pass through the card so that there is no electrical contact, it should make no difference if the energy is indeed only guided by the conductors, but all the difference if the conductors carry the energy. I do not have the facilities to test for reflection in the varnished and unvarnished cases, but if anyone does I would be glad to know the result.

Chris Parton
Uddingston
Glasgow

ENERGY TRANSFER

With reference to the energy-transfer controversy, I agree with Mr Catt that the velocity of electrons in conductors is too low for the role of the primary transporter of energy along transmission lines, but I cannot agree with his contention that the energy transport takes place in the space between the conductors, in the form of "energy slabs". It is a fact that the electromagnetic fields (or more precisely, the physical phenomena that have given rise to the concept of the

electromagnetic field) are most intense in the immediate vicinity of the conductors, which strongly suggests that the primary transporter is concentrated in the conductors. Accordingly, I would like to put forward the following explanation of the transfer mechanism.

Conductors of electricity are substances which contain free electrons. Although to a first approximation these electrons may be visualised as a more or less stable "electron gas" or "fluid", it is a well established fact that each free electron has only a limited lifetime, and there is a continuous process of electron-hole generation and recombination. The process is accompanied by the absorption and emission of quanta of energy (photons), which travel from atom to atom at the velocity of light, but in theoretical studies of electrical conductivity this elusive "photon gas" is not considered in any detail, and the emphasis is on the tracks and lifetimes of the much more tangible electrons and holes.

My suggestion is that it is in fact the photon gas that constitutes the primary transporter, since in addition to having the correct velocity of propagation, it can also explain the "two superimposed slabs of energy" concept which Catt used to account for the fact that when a transmission line is charged from a d.c. source and then discharged into Z_o, the resulting pulse is twice as long as could be expected on the basis of existing theory (*Wireless World*, December 1980, Page 80). But the slabs would not be concentrated in the space between the conductors. They would be most intense in the conductors, or in the outer layers of the conductors, and would be mere mathematical devices representing the inntegrated effect of the individual photons.

I must add that when the theory of electron-hole generation and recombination was developed in connection with semiconductor processes, it was found that the rate of

recombination was much faster than could be expected on the basis of chance encounters between electrons and holes — a difficulty which led to much work before a more satisfactory picture emerged. This suggests

that the photon gas mechanism too might be rather complicated; it might even involve photon-photon interactions of the interference pattern type that has defied all attempts at commonsense explanations. But there can be little coubt that if the primary transporter of energy along transmission lines is concentrated in the conductors, as is almost certainly the case, then the most likely canndidate for that role is the photon.

Assuming that the above explanation is substantially correct, another question would arise — what would be the physical nature of the electromagnetic fields which according to classical theory are supposed to be closely associated with conduction phenomena? The answer seems to be that there would not be any physically real "fields" in the sense of regions of space where "pure energy" is stored without the active involvement and participation of physically real particles. A "field" would be nothing more than a purely imaginary device for predicting how individual particles or aggregates of particles would behave in the proximity of other particles and aggregates, and how particle distribution patterns evolve.

G Berzins
Camberley
Surrey

Once upon a time there lived a chap called Fleming who gave his first name to creamed rice. He was a handy sort of fella. A little later a nutter called MacHarg took both the right and left hands of Fleming and tied together his index fingers so that they could interact, and his middle fingers so that they could interact also. He then discarded Fleming's lesser fingers, two on each hand, but left the thumbs attached.

A well known magician hitched a funnel on to one thumb and poured milk into the funnel: he then milked the other thumb into a pan, so provicing something to cook the rice with as food for thought, if not a lot.

At least the experiment demonstrated that between action and reaction there lies interaction which occurs in the middle of the playground, a necessity if anything is actually

to happen such as a transfer of energy between dynamo and motor, deus and machina. The four horsemen involved in the interaction may be worthy of note.

However, if one wishes to involve c, it may be a good plan to first determine what c.

actually is: I suggest that interaction is faster than c, but that action and reaction might occur at c. (Thank you again Roy Hodges.)

As noted in my letter of February 1983, this will require a massless sensor for energy, not only to disprove it, but also to prove it. Doubtless the pages of *WW* will continue to resonate with arguments on the subject until such a wondrous device is invented, so to be ensured of interminable life! (Thank you, too, Providence.)

When the said wondrous device is invented, we shall also be able to determine whether the interaction between a photon and an orbiting electron is concrete (as with a rack and pinion) or abstract (as with induction). It seems to matter if c is to discover its real identity.

After all, if energy can move faster than our senses or anything else can react, then apparent action at a distance at last becomes conceivable.

That was quite a Catt you let out of the bag, Mr Hodges!
James A. McHarg
Wooler
Northumberland

It is precisely because Ivor Catt does not distinguish between resistance and impedance that his theories fail. For a step function a transmission line behaves like a resistor. Initially, current and voltage are in phase but that is the only

resemblance. Resistance has the exclusive property of turning electrical energy into heat: all energy arriving at a resistor is turned into heat. A loss free transmission line, by definition, transmits the energy. To understand transmission lines properly it is essential to take proper account of the vectors involved: a TEM wave in a transmission line has the electrical and magnetic field vectors are at right angles to the direction of propagation. They are also at right angles to each other. If the line is lossy one or both of these conditions does not hold, if the line is

correctly terminated by a resistance, but what am I saying? The dimension of length is not needed to describe a resistor, perhaps the average quarter watt is really just another of these transmission lines like Catt's capacitor, another Dogg's dinner of confusing waves.

Ivor Catt may believe that modern physics is seriously divided over electrical theory but he has produced no evidence of this. He has shown a truly amazing lack of knowledge of what current theory is about (does anybody really believe that perfect capacitors are physically realisable?) His latest letter (May, 1985) is another fine example. Of course the currents in the two conductors cancel, it would be the same with two batteries in series and two

resistors in place of transmission lines. This property of current summing to zero is widely used in three phase power transmission: in some applications the three phases have no common return, amazing, isn't it?

It is indeed hard luck on Mr Potter that in the same issue (April, 1985) as his letter, there was a very good article about badly matched antennas (How long is a piece of wire? — J.J. Wiseman) I'm sorry to (try to) disillusion him but unterminated lines do radiate, perhaps not very much at 50 Hz, but things can get quite exciting if you are trying to transmit power much above 1000 km and you don't account for transmission line effects at a million volts! Yes, waveguides radiate if left open, the efficiency depends on the degree of match, which is generally quite good for waveguides and rather poor for wall sockets! To assume the impedance of free space is some sort of universal all pervading resistance of 377 ohms is to make the same mistake as Ivor Catt and to display the same degree of ignorance.
Dermod O'Reilly
Antwerp
Belgium

ENERGY TRANSFER

I fear it is not I that have misunderstood Ivor Catt (July Letters), rather the reverse.

In my June letter I pointed out that superposition of forces could not be expected to succeed when the forces in question were quadratic functions of current or voltage. I then proceeded to illustrate this claim by reference to a simple situation in electrostatics, and concluded with a derivation of the magnetic force from Special Relativity.

I fear these last two points detracted from my argument, and confused Mr Catt.

Mr Catt is upset that I choose to overturn his arguments (concerning forces between conductors guiding t.em waves) by discussing static currents and voltages, while he allows himself the privilege of building his arguments by reference to these same static forces. However, I would assert that there is no difference between the static case (with suitably chosen values of current and voltage), and the momentarily quiescent state in the middle of a broad pulse. If Mr Catt thinks that there is a difference then he cannot use the static case to prove that the force between conductors carrying a pulse is zero.
N.C. Hawkes
Abingdon
Oxfordshire

I wonder if some of the conceptual difficulties with the transmission line stems from the assumption — and it is an assumption — that power density in an em wave is measured by Poynting's vector? (Do I hear cries of dissent? But who remembers what Poynting's theorem actually says?) In fact there are any number of vectors that would be equally valid.

One such is Slepian's vector.

$$S = E \times H + \text{curl}(VH)$$

where V is the electric potential. Poynting's vector tells us that the power flows through the space surrounding the wires, i.e. is carried by the em wave. Slepian's vector, on the other hand, tells us that all the power flows through the wires! It seems that either view

is "true, but not exhaustive" (Churchill's phrase).

As an engineer I welcome this. It means that I can adopt either point of view, whichever is more convenient for the problem in hand.

Interested readers should consult "The Electromagnetic Field in its Engineering Aspects" by G.W. Carter (Longmans, 1954) Professor Carter devotes the whole of Chapter 13 to the flow of energy in an electromagnetic field.

P.L. Taylor
Marple
Cheshire

ENERGY TRANSFER

Since Ivor Catt has questioned the normal view of electric current, I would like to mention a problem which has troubled me since my student days, relating to the Hall effect in p-type semiconductors.

A charge Q moving through a magnetic field B experiences a Force $F = BQ v \sin \zeta$ where is the velocity of the charge and is the angle between the velocity and the field, with the direction of F given by Fleming's left-hand rule.

It follows that when a negatively charged electron is moving along a wire through a perpendicular magnetic field, it will be forced to one side of the wire as shown in Fig. 1, where a current-carrying wire acquires a Hall voltage. Once this voltage is established, the electrostatic force balances the magnetic force. This works equally well in the case of n-type semiconductors. However, in the case of p-type semiconductors the measured Hall voltage is reversed. This is said to be because the majority charge carriers are positive "holes" moving in the opposite direction, as shown in Fig.2. My problem is that no positive charges actually move; it simply appears that they do, in the same way that a "free seat" appears to move backwards along a doctor's waiting-room queue, as patients (electrons)

B field into paper

Conductor or
n-type
semiconductor

p-type
semiconductor
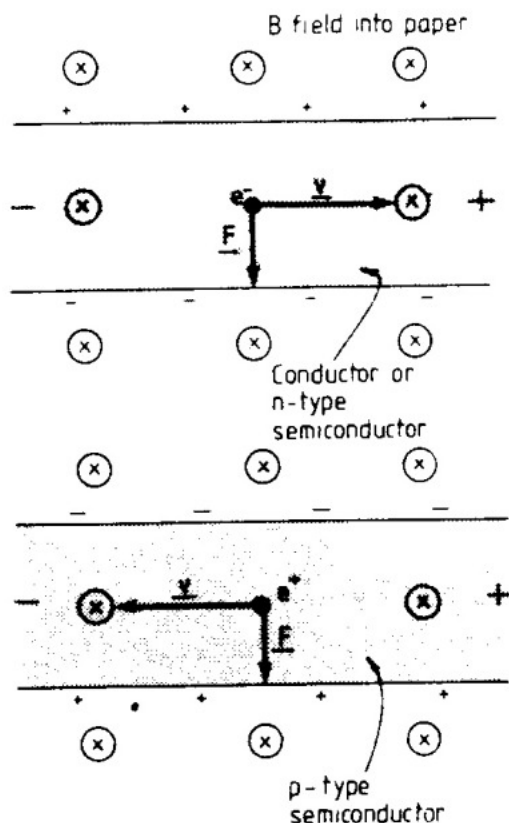
move one place forward when the space (hole) is immediately in front of them. In fact, the patients are moving forward and nothing is moving backwards. A force cannot push against nothing.

Even if one believes that a force can act upon a massless "hole" (which Newton would find difficult), whenever the hole moves one step one way, an electron would automatically be moving the other way at the same speed, therefore presumably experiencing the same force, the two effects cancelling and the nett Hall voltage being zero.

My interpretation of the established theory doesn't agree with experiment.

R. Petzeratt
Brighton   NOVEMBER 1985

Following the debate in *WW* concerning the nature of electric current, Ivor Catt has shown that the establishment explanation of electric current, consisting of moving electronic charges, is anomalous. However, it may be that the reluctance of many readers to accept these anomalies is due to this explanation being so closely associated with the model of the atom with which we have all grown up. If the established theory of electric current is indeed inextricably linked to this model of the atom, so that if one fails the other collapses, it might be useful to look back again at the roots of this view of the atom.

Following Dalton's atomic theory of 1803, the atom had been regarded as the smallest possible particle of matter. However there was a

disagreeably large number of types of atoms (elements) on the Periodic Table, and it seemed sensible to look for something more fundamental. Simple atomic structures were devised, starting with the "plum pudding" atom, and later the "nuclear" atom of Ernest Rutherford in 1904, according to which all atoms were built of a nucleus containing protons and electrons surrounded by a system of orbitting electrons. The attractiveness of this atomic model was largely due to its overwhelming simplicity. It replaced more than ninety "starting points" with just two.

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The theory won over the establishment, so that later, despite modifications of structure by Nils Bohr and others, the two particles remained.

Armed with this model, physicists soon investigated the atom further, and found that various loose ends didn't quite tie up. In order to save the theory, just as Thomas Kuhn describes in "Structure of Scientific Revolutions", extra *ad hoc* hypotheses were added to the original theory. Physicists made their names by discovering new fundamental particles, behaving as scientists in the Kuhnian "Normal science" mode, each particle being just right to plug its particular gap. Today, on top of the original two, we have collected a veritable zoo, including neutrons, photons, positrons, neutrinos, pions, muons, nuons, and other strange particles which refuse to behave as they ought, plus all their anti-particles, not to mention the speculative gravitons and tachyons, giving us a total of well over thirty.

If Rutherford had originally proposed this many fundamental paticles with such peculiar properties, however well it performed, it would have been rejected as absurd, and physicists would have sought a better answer. More recently, dissatisfied physicists have made somewhat abortive attempts to build these "fundamental" particles from even more fundamental "quarks", but seldom has anyone seriously questioned whether Rutherford's basic idea could have been wrong.

Oliver Fish
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One notices how many contributors to Mr. Catt's enquiries into the existence, or otherwise, of electric 'current', have been folk steeped in line-transmission knowledge. And who as such have been able to clearly distinguish between R pure and simple, and the R+jx aspect of practival transmission system.

The question which has been lodged in the writer's mind, ever since Mr Catt lauched his views, is "what is the behaviour of a long line when subject to low-temperature super-conduction conditions"? always supposing any source of an applied e.m.p. is sans either 'R' or 'R+Jx'. One imagines the velocity of propagation would be equal to that of free space, but what of phase ange considerations?

First go to Mr Catt please.

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Hurstpierpoint
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ELECTROMAGNETIC THEORY

Volume 2

By

Ivor Catt

FORCE ON CONDUCTORS GUIDING A TEM WAVE

After a TEM wave step has passed by, guided by two parallel conductors, there remain two steady state "fields",

1) Electric current flows down the wires, and a B field exists in the dielectric right next to the surface of the conductor.

2) Electric charge remains on the surface of the conductors, and an E field exists in the dielectric right next to the conductor.

The magnetic field exerts a force into the conductor; that is, a force which tends to drive the conductors apart. The electric field exerts a force out of the conductor; that is, a force which tends to pull the two conductors together.

The forces are $F_1 = iB$, $F_2 = qE$.

Now the electric current in the surface of the conductor i and the electric charge in the surface of the conductor q are related by the equation $i = q \copyright$. That is, the current is equal

to the speed with which the charge density travels along the surface of the conductor. Dividing, we find that numerically,

$$\frac{F_1}{F_2} = \frac{i}{q}\frac{B}{E} = \frac{© B}{E} = \frac{1.(\mu H)}{\sqrt{\mu \epsilon}.E} = \sqrt{\frac{\mu}{\epsilon}} \quad \frac{H}{E}$$

But we know that in a TEM wave, at every point $E/H = \sqrt{\mu/\epsilon}$
Therefore $F_1 = F_2$ numerically.

We conclude that when a TEM wave (which we call a Heaviside signal) glides along between two conductors at the speed of light, there is no force on the conductors guiding the signal. This very interesting feature of a Heaviside signal was first pointed out by David Walton, and is here proved.
(For the equations giving F_1 and F_2, see for instance P. Hammond, "Electromagnetism for Engineers", Pergamon, 1978, pages 107 and 55.)
It is generally thought that if an electromagnetic wave travels down a coax cable from left to right and passes through another such wave travelling from right to left, then superposition applies. However, this

The hidden message in Maxwell's equations

Did Maxwell lodge with his bank the answer to his mathematical bluff, Maxwell's Equations, with instructons to open and publish a century later? And did the bank lose the envelope?

by Ivor Catt

Historically, the theory of electrodynamics grew out of the theory of static fields, electric and magnetic. These static fields resulted from steady electric currents and static electric charge. Maxwell wrestled with the paradox of the capacitor[1,2], and this led him to reassert Faraday's idea of "the propagation of transverse [electro] magnetic [waves][3]." So the concepts of electric charge and electric current preceded the concept of a transverse electromagnetic wave[4], and it is generally agreed (but not by me) that the t.em. wave follows from the prior postulation of electric charge and current[1,2].

A strong case can be made for the view that the t.em. wave is a more fundamental Primitive, or starting point, for electromagnetic theory than electric charge and electric current.

- When light and heat reach us from the sun, it is by the mechanism of a t.em. wave, not electric charge and current.

- Kip[5] says that the energy dissipated in a resistor entered it *sideways*, and was transported into the resistor by the t.em. wave.
- In 1898 J.A. Fleming[6] wrote that 'although we are accustomed to speak of the current as flowing in the wire,. . ., (it) is, to a very large extent, a process going on in the space or material outside the wire.'
- In *Wireless World*, May 1985, page 18, in a reply to G. Berzins, I showed that the t.em. wave, not the electric current, must be the mechanism by which energy is transferred.

- We all adhere to the underlying primitive 'conservation of energy'. Now energy is transported by the t.em. wave, not by electric charge and electric current.

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C.A.M.

• We all adhere to the underlying relativistic primitive, 'no instantaneous action at a distance'. While electric *charge* could be argued to be located at only one point in space-time, this is not true of an electric current, some of which is necessarily located at the same time at points which in the language of Minkowski are 'elsewhere' to itself.

Catt's equations of motion for a tapering wooden plank

Consider a plank of wood tapering to a point at the front, travelling at velocity v. The aspect ratio of the wood's cross section is z. Height and width at any point are
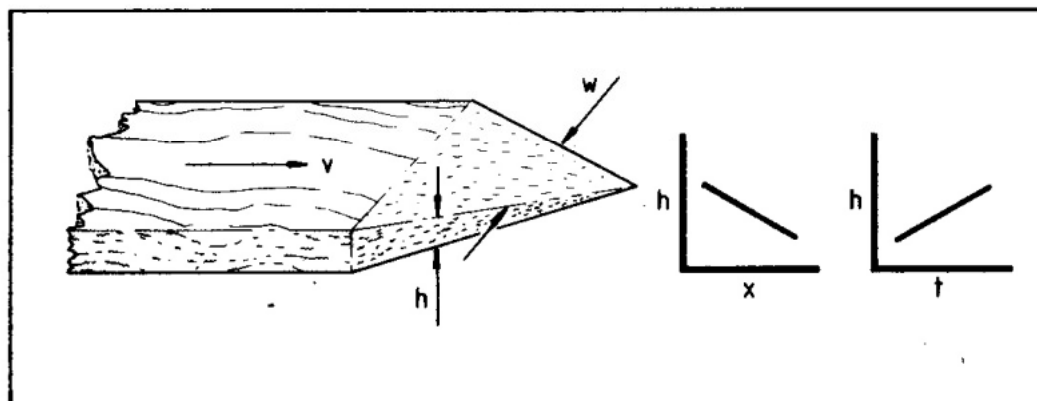
denoted by h and w. Within the tapering section, the ratio of height to width remains z.

The velocity of the plank is the factor which relates the change of height with forward distance to the change of height at a point with time, so from first pinciples, we can write

$$\frac{\partial h}{\partial x} = -\frac{1}{v}\frac{\partial h}{\partial t} \text{ *(refs 7,8).} \qquad 1$$

Since we have stated that at any point, h/w = z, we can substitute for h in equation 1:

$$\frac{\partial h}{\partial x} = -\frac{z}{v}\frac{\partial w}{\partial t}. \qquad 2$$

Again from first principles, we can write

$$\frac{\partial w}{\partial x} = -\frac{1}{v}\frac{\partial w}{\partial t}. \text{ *} \qquad 3$$

In the same way as we substituted for h in equation 1 to get (2), now substitute for w, to get

$$\frac{\partial w}{\partial x} = -\frac{1}{vz}\frac{\partial h}{\partial t}. \qquad 4$$

Equations 2 and 4 we define as Catt's Equations of Motion for a wooden plank. Note that they hold true for any type of taper, and even for a straight portion of the plank, when both sides of the equations are equal to zero. The only imposed limitation is that h remain proportional to w.

* For explanation of the minus sign, see ref.9.

Catt's equations of motion for a thick warm plank

We postulate that a thick plank of wood travels forward with velocity v. At every point within the plank, we postulate that the temperature T is proportional to the density of the wood ρ, so that $T/\rho = z$. (To picture this, think of spontaneous combustion.)

Catt's equations 2 and 4 now become

$$\frac{\partial T}{\partial x} = -\frac{z}{v}\frac{\partial \rho}{\partial t} \qquad 5$$

$$\frac{\partial \rho}{\partial x} = -\frac{1}{vz}\frac{\partial T}{\partial t} . \qquad 6$$

These equations remain valid for two thick short planks moving forward side by side. ·

Maxwell's equations compared with two thick short planks

Let us first review two of the many extant versions of Maxwell's Equations for a vacuum.

$$\frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t} \qquad 7$$

$$\frac{\partial H}{\partial x} = -\frac{\partial D}{\partial t} . \qquad 8$$

The version above has been obscured by the introduction of alternative symbols B and D to denote magnetic and electric fields. Our purpose is more easily served if we use another of the many versions that litter the text books (ref. 2):

$$\frac{\partial E}{\partial x} = -\mu_0\frac{\partial H}{\partial t} \qquad 9$$

$$\frac{\partial H}{\partial x} = -\epsilon_0\frac{\partial E}{\partial t} . \qquad 10$$

Our problem is that whereas the equations for planks have constants v for velocity and z for ratio, Maxwell's Equations have the obscure symbols μ_0 and ϵ_0. However, this problem becomes trivial because it is known from experiment that

— the velocity of light or a t.em wave is $c = 1/\sqrt{\mu_0 \epsilon_0}$
— the ratio between E and H at any point, described by the symbol Z_0, has been found by experiment to be equal to the constant $\sqrt{(\mu_0/\epsilon_0)}$.

By algebra, we find that $\mu_0 = Z_0/c$ and $\epsilon_0 = 1/cZ_0$ (ref.10). We can now see that equations 9 and 10 are in fact 5 and 6, Catt's equations for two thick short planks, and contain virtually no information about the nature of electromagnetism.

The hidden message in Maxwell's equations

In general, Maxwell's Equations tell us only the obvious truisms about any body or material moving through space. It is the obscurantism of the fancy maths in which they are dressed that has for the last century caused scholars to think that they contain significant information about the nature of electromagnetism (but see refs 7 and 9). Most versions are far more messy and obscurantified than the two comparatively

clean versions (7) through (10) listed above. Other versions tend to contain a mixture of integrals, divs, curls, and much more, leading to a head-spinning brew, see for instance refs 1, 13. (For the

Inscrutable Ultimate, see panel for Chen-To Tai.)

Two questions arise:
— do Maxwell's Equations contain any information *at all* about the nature of electromagnetism?
— why do academics and practitioners generally believe that Maxwell's Equations are useful?

The answer to one of these turns out to be much the same as the answer to the other.

Returning to equation 1, this is only valid if the constant in the equation equals the velocity of propagation v. When we then mix together h and w to produce the hybrid equations 2 and 4, they only remain true if h and w are always in fixed proportion z. So we find that Maxwell's Equations 9 and 10 are only true if at every point in space E is proportional to H, and also if the velocity of electromagnetism has the fixed value c. So the only information about electromagnetism contained in the apparently sophisticated equations 9 and 10 is about the two ruling constants in electromagnetism: the fixed velocity c, and that E,H at every point are in fixed proportion Z_o. The remaining content of Maxwell's Equations is hogwash.

We have to conclude, with respect, that what Maxwell and his sycophants do not say about a tapering, disappearing plank of wood isn't worth saying.

Now move on to the second question, "Why do academics and practitioners generally believe that Maxwell's Equations are useful?" The answer to this question, deriving from the previous discussion, is extraordinary. We have already seen that Z_o and c are the only items of information buried in Maxwell's Equations. We resolve the paradox by pointing out that

Z_o is not available as a concept to the whole of the fraternity called 'modern physics'.

The only way they can use such a necessary constant in their work is by taking on board with it all the meaningless rubbish in Maxwell's Equations which shrouds this valuable nugget.

In September 1984, in a paper delivered to a learned conference[11] and in that month's issue of *Wireless World*, I wrote: "It is noteworthy that Einstein himself and also the whole post-Einstein community who call themselves 'modern physics' never mention the impedance of free space $\sqrt{\mu_o/\epsilon_o}$, although it is one of the key primitives on which digital electronic engineering is based. The reader is encouraged to look for reference to it in the literature of 'modern physics'." Since then, no one has pointed out any case where it is mentioned in the literature. It follows that

The only purpose served by Maxwell's Equations is as a package to deliver the constant Z_o to the theorist and to the practitioner.*

If they lacked another source for it, c could also be accessed via Maxwell's Equations, but I think that to some extent c is available via other routes, although university lecturers remain muddled and vague about the velocity of a t.em. wave. Curiously, they are much more sure that the velocity of light equals the constant c.

Did Maxwell lodge with his bank manager the answer to his mathematical bluff, Maxwell's Equations†, with instructions to open and publish a century later? Did his bank lose the envelope? Should we say to Maxwell now, as he sits laughing, or perhaps

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* A bit like burning down your house to get roast pig.

† The meticulous student might like to follow up the assertion by H. J. Josephs that Heaviside, not Maxwell, wrote Maxwell's Equations. Is it true that Maxwell's writings do not contain Maxwell's Equations? This issue does not effect the discussion. Certainly my hero Heaviside fell hook, line and sinker for Maxwell's Equations. Nobody's perfect. According to Dr D.S. Walton, "The physical substance is in Maxwell's writings, but the formal expression that we are familiar with is due to Heaviside".

smarting, on Cloud Nine, "Now pull the other leg?" No. I am sure that Maxwell was sincere, and did not knowingly shroud the very heart and soul of science, Electromagnetism, in confusion and nonsense for over a century.

Appendix

It is worth repeating here from ref. 7 that the following two source equations, from which Maxwell's Equations are derived, have never been mentioned in the literature:

$$\frac{\partial E}{\partial x} = - Z_o \, \epsilon_o \, \frac{\partial E}{\partial t}$$

$$\frac{\partial H}{\partial x} = - \frac{\mu_o}{Z_o} \frac{\partial H}{\partial t} \, .$$

These are similar to equations 9 and 10. The alternative form is

$$\frac{\partial E}{\partial x} = - Z_o \frac{\partial D}{\partial t}$$

$$\frac{\partial H}{\partial x} = - \frac{1}{Z_o} \frac{\partial B}{\partial t} \, .$$

These are similar to equations 7,8. The cross-linkage of electric and magnetic fields E and H in Maxwell's Equations only obscures the issue. There is no interaction between E and H. (Similarly the *width* of a brick does not interact with its *length*.) They are co-existent, co-substantial, co-eternal (refs 12,14).

Historical background reading

What did Maxwell do? What did he say that he did? Today, what do scientists believe that he did?

Did Maxwell postulate 'The Extra Current', now called Displacement Current, to resolve an anomaly which arose from the capacitor in a closed circuit? Or did he later falsely claim it as his reason? Or is it merely the false reason given in the history books? It is possible to argue that for my purpose these distinctions are unimportant, because if unknown, they do not influence the contemporary scene. (All the same, I believe that the true history of science is very important.)

Generally, I attempt to bypass these niceties, in order to create an uncluttered discussion of the technical flaws in today's science. By contrast, historians,

lacking proficiency in electromagnetical theory, assume that today's situation is sound, and the only problem is that there are errors in our knowledge as to how we reached it.

This difference — that I am concerned with flaws in the contemporary body scientific and less concerned with historical detail — creates an uneasy relationship between the historians and me. As a result, I both do and do not want to point the reader to historical analysis of Maxwell exemplified by the following:

Chalmers, A.F., Maxwell and the displacement current, *Physics Education*, vol.10 1975, p.45

Gee, B., Models as a pedagogical tool: can we learn from Maxwell? *Physics Education*, vol.13, 1978, p.287.

Tai, Chen-To, On the Presentation of Maxwell's Theory, *Proc.IEEE*, vol.60, no.8, Aug.1972, p.936.

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3. *ibid*, p.314. Kip quotes Maxwell as saying that Faraday proposed transverse waves.
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   Catt, I., The Heaviside signal, *Wireless World*, July 1979, p.72.
5. ref.2, p.327.
6. Fleming, J.A., Magnets and Electric Currents, 1898, p.80, quoted in *Wireless World*, Dec. 1980, p.79.
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9. *ibid*, pp.112, 281, 313.
10. ref. 8, p.237.
11. Catt, I., The Fundamentals of Electromagnetic Energy Transfer, International Conference on Electromagnetic Compatibility, Surrey University, IERE Pub. 60, Sept. 1984, p.57.
12. ref. 4, 2nd item also Oct. 1984.
13. Plonsey, R. and Collin, R.E., Principles and Applications of Electromagnetic Fields, McGraw-Hill, 1961, pp.301,311. Also Chen-To Tai (see panel).
14. Catt, I., Letter *Wireless World*, Feb. 1984, p.51.